IMPACT OF CLIMATE CHANGE ON EAST-RATHONG GLACIER IN RANGIT BASIN, WEST SIKKIM

Keshar Kr. Luitel, D. G. Shrestha, N.P. Sharma and R. K. Sharma

ABSTRACT

The Himalayas, as the name suggests, is the home to the largest concentrations of snow and glaciers outside the polar region. Various reports suggest that a significant number of mountain glaciers are shrinking due to climate change and global warming. Study of these glaciers is one of the most important and challenging tasks. East-Rathong glacier in West-Sikkim feeds the Rathong Chu River. The present snout of this glacier has retreated 460 meters during the last 33yrs. The present location of the snout of the glacier can be found with the help of Survey of India (SOI) topo-sheet, LISS III Satellite image of 1997, 2002, 2004, 2009, Landsat TM Satellite imagery of 1976 and 1988 and data from Field using Global Positioning System (GPS) and Altimeter. The rate of retreat of the glacier was calculated with help of satellite imageries and ground truthing. The average retreat of 13.3m/yr. of East Rathong Glacier is less then the rate of retreat of alike Himalayan glaciers in the Western Himalaya. Small glacier like East Rathong shows some retreat as it is South facing and accumulation zone of the glacier is on steep slope where as large glacier like Zemu with East facing aspect and gentle slope does not show any significant response to global warming.

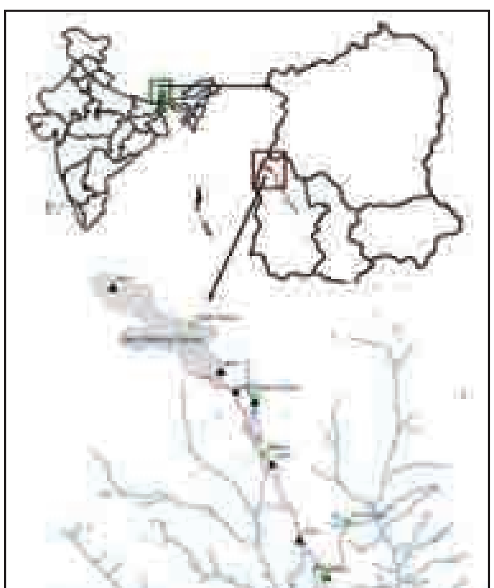
KEYWORDS: *DEM, East-Rathong, Retreat, Satellite imagery, Sikkim Himalaya, Zemu glacier*

Fig.1: U - shape valley on the way to East Rathong Glacier in West Sikkim depicting the deglaciated region

Fig.2: East Rathong Glacier, West Sikkim

Himalayan glaciers have been in a state of general retreat since 1850 (Mayes & Jeschke 1979) and recent publications confirm the finding. Also the rate of retreat is accelerating Jangpang and Vohra (1962), Kurien and Munshi (1972), Srikanta and Pandi (1972), Vohra (1981)), and many others have made significant studies on the glacier snout fluctuation of the Himalayan glaciers. A dramatic increase in the rate of retreat has been reported during the last three decades.

There are 84 Glaciers in the Teesta basin and the East-Rathong Glacier is one of them (Glacier Atlas of Teesta Basins 2001). Due to climatic change the number of glacier field is increasing, but the total area of the glaciated region is decreasing continuously. Obviously, this will have a profound impact on snow accumulation and ablation rate in the Himalaya, as snow and glaciers are sensitive to global climate change. In response to climate change, the glaciers in the major mountainous regions of the world such as Himalaya, Alps, Rockies and Andes are retreating (Kaab et al. 2002; Casassa et al. 2002). Glaciers in Caucasus mountain have retreated from 700 to 3000 m in the last 100 years, that is, average rate of retreat of 30m per annum. (Mikhalenko 1997). Investigations in the Baspa basin in India have shown an overall 19% deglaciation from 1962 to 2001 (Kulkarni and Alex 2003). Investigations carried out in the Himalayas suggests that almost all glaciers are retreating and the annual rate of retreat varies from 16 to 35 m (Dobhal et al. 2004; Oberoi et al. 2001).When the ice fields are broken, the formation of moraine dammed lakes takes place. Based upon the morphological characters, the East-Rathong Glacier is a Valley Glacier and is south facing. The glacier is clean and is free from debris, both the sides of the glacier is bounded by lateral moraines, and the surrounding valleys are characterized by a number of hanging glaciers. The mouth of the glacier turned towards South-South East and the total area of the glacier has been reduced from 6.72 sq km to 4 sq km on 2008 from the last terminal moraine marked on Survey of India (SOI) topo sheet as well as observed during field expedition.



Location Map of East Rathong Glacier

LOCATION

The area under study falls in the Survey of India topo-sheet no. 78A/2 in the West district of Sikkim. It lies between 27°36’00” and 27°33’00” N latitude and 88°06’00” and 88°07’00” E longitude. The metalled road to Yuksam is approachable from Gangtok via Ravongla, South Sikkim. From Yuksam to the glacier under study is through an arduous 39 km. foot trek [Yuksom to Tshoka (16kms), Tshoka to Dzongri (10 kms), Dzongri to Bikbari (8kms. and at an elevation of 4000m amsl), Bikbari to HMI base camp (3kms) and HMI base camp to study area (2km)]. The East Rathong Glacier is within the Khangchendzonga National Park. Near the mouth of the Glacier is a pass called Yalung pass. The Sikkim-Nepal border runs NNE-SSW direction along Khangchendzonga range.

PHYSIOGRAPHY

The West district of Sikkim is one of the most difficult and rugged part of the state. The Khangchendzonga range starts from this area and snow fall is not unusual even in summer in this area. The eastern Himalayan glaciers are monsoon fed glaciers (Hasnain 1999). The sub-basin code of this glacier is 78A02004 (Glacier Atlas of Teesta Basins 2001), the river Rathong Chu originates from the snout region of the East-Rathong glacier which is at 4674m above mean sea level and flows in an easterly direction as the main tributary of Rangit river.

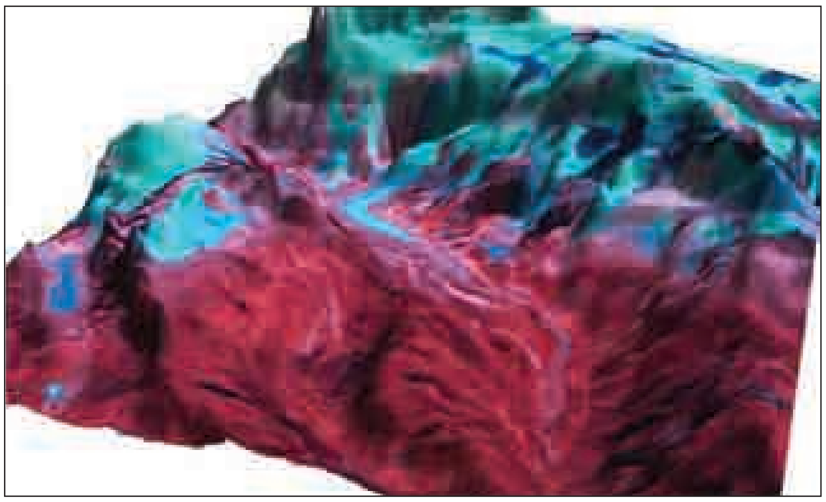


Fig.3: Digital Elevation Model of East Rathong Glacier

CLIMATE

The study area experiences wet and cold climate, although the monsoon is active in the target area from June to August and snowfall is not unusual even during monsoon. During winters the area gets heavy snowfall.

GEOLOGY OF THE AREA

The rock types in the study area are the garnetiferous-banded biotite gneisses and augen gneisses with occasional bands of amphibolites and pegmatite veins. The banded augen-gneisses are found to high percentage of quartzo feldspathic materials near the contact zone. The individual bands are less than a meter to more then 50 meters thick. The rock in general is a medium grain to coarse grain leucocratic granitoid. The size of quartz and feldspar in augen gneiss varies with elevation in the study area. At lower belts schistose rocks are observed and they have undergone folding and physical weathering due to orogenesis. The rocks encountered at glaciers snout are gneiss and quartzite and due to physical weathering the rocks are fractured and jointed and disintegration to blocks which are on the verge of mobilization. At places due to the weathering process of frost and throw, rocks are cemented to boulders and debris.

Tentative age	Formation	Main lithology
Recent to sub-recent	Quaternary deposits	Glacial moraines, scree and hill wash materials
Post-Precambrian	Rathong granite	Predominantly non-foliated biotite granite
Pre-Cambrian	Chhubakha series	Fine grained augen and banded often garnet bearing with extensive intrusion of biotites hornblende and tourmaline granites lime silicate rock (biotite, feldspar, quartz bearing)
Pre-Cambrian	Darjeeling gneiss stage	Augen and banded gneisses ortho gneiss with quartz bands

GEOMORPHOLOGY OF THE AREA

East-Rathong is a 5.12 km long North-South flowing valley glacier with an average width of 1.50km. It originates at an elevation of 6000masl and descends with a gentle gradient. The glacier is within a U-shaped valley. Around snout region is an ice cave, on top of which are moronic materials. There are four small hanging glaciers on either side of the main glacier body, their melt streams join the main stream just below the snout.

Fig.4: Lateral moraines of the glacier

METHODOLOGY

The oldest information about extent of East Rathong Glacier is available on Survey of India topographic map No. 78A/2 (1:50,000 scale; 1965). Mapping of glacial extent in 2008 was carried out with the help of field observation (April-May 2008) and using the time series satellite imagery of Indian Remote Sensing Satellite Linear Imaging Scanning Sensor (LISS) III sensors and Landsat TM satellite imageries. The January images were selected for the study, because during this period, snow cover is at its minimum and due to clear sky the glacier is fully exposed. Glacier boundary was delineated using topographic maps, with help of field data through Geographic Information System (GIS). The glacial boundary was mapped on satellite imagery using standard combinations of bands. Image enhancement technique has been applied to differentiate between lateral moraine and the snout position of the glacier and demarcation of the deglaciated area was done during field expeditions. Surface Radar Topographic Mission (SRTM) Digital Elevation Model is used for creation of 3-D model of the East Rathong glacier valley.

GLACIAL RETREAT

The retreat of the glacier from 1976 to 2009 is around 460 meters and during 12 year period from1997 to 2009, it was 234 m. The retreat of glacier was measured along the centerline. The investigations suggest that the glacier shows a retreating trend. The rate of retreat is 19.5 m/year during the last 12 years. This rate of retreat

Fig.5: Field photograph showing down wasted area and Terminal moraines of East Rathong glacier.

is similar to like Himalayan glaciers in western Himalayas. The high retreat comprises a significant portion of the low flow of Himalayan Rivers as during the dry season snow and glaciers melt in the Himalayan region and feed the rivers. The runoff supplies communities with water for drinking, irrigation and industry, and is also vital for maintaining river and riparian habitat. It is possible that the accelerated melting of glaciers will cause an increase in river levels over the next few decades, initially leading to higher incidence of flooding and land-slides as per International Panel for Climate Change (IPCC 2001a). But, in the longer-term, as the volume of ice available for melting diminishes, a reduction in glacial runoff and river flows can be expected (IPCC 1996b, Wanchang et al. 2000).There was a flood in Rathong Chu river in 1998, but establishing the correlation between this incident needs more time series climatological data.

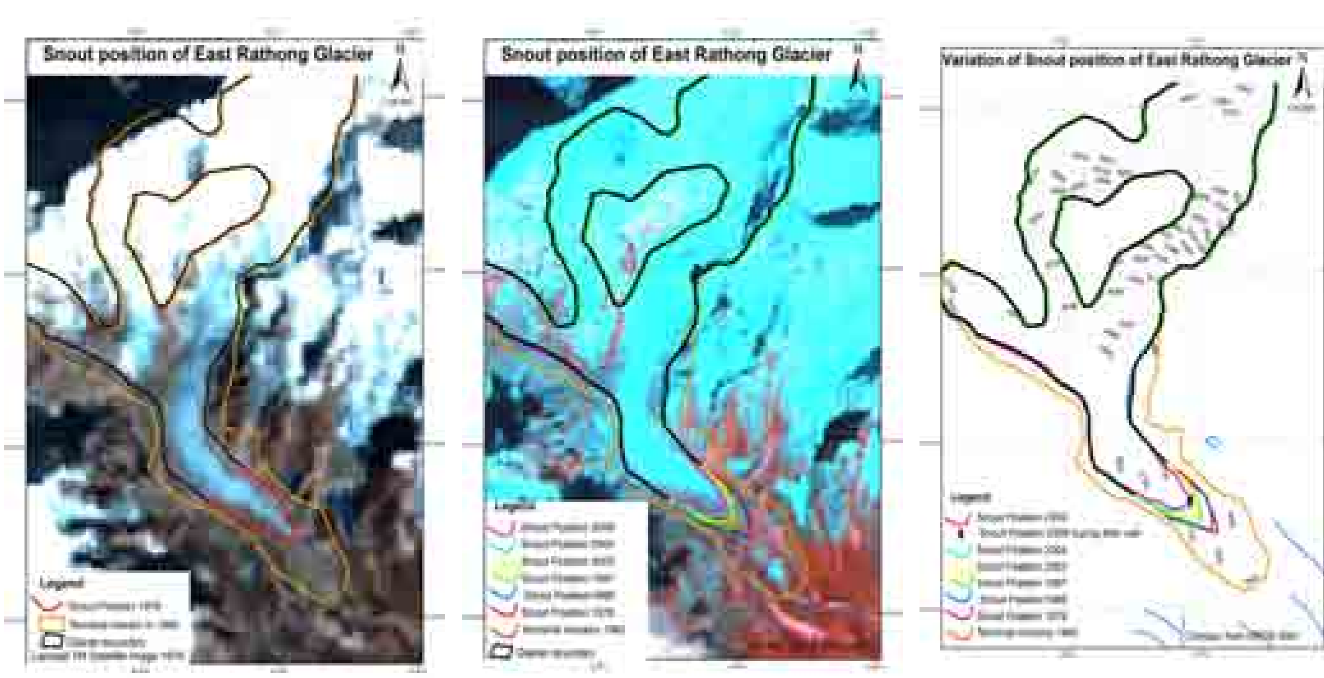


Fig.6: Moraine dammed lake in the south eastern part of East Rathong Glacier

Fig.7: Ice blocks separated from the main glacier body of East Rathong Glacier

Table 1: East Rathong Glacier West Sikkim, Teesta basin (sub-basin Rangit)

Year	Snout Elevation (Meters)	Width of the glacier in Ab-zone	Loss of width(m)	Length of glacier(along NW-NE direction) in m	Loss of length(m)
1965	4600™	697		5117	
1976		497	200	4462	655
1988		435	128	4404	58
1997		369	66	4236	168
2002		340	29	4151	85
2004		299	41	4018	133
2008	4674	298	1	4007	11
2009		296	2	4002	5

TM- Terminal Moraine **GL- Glacier**

Ab- Ablation zone

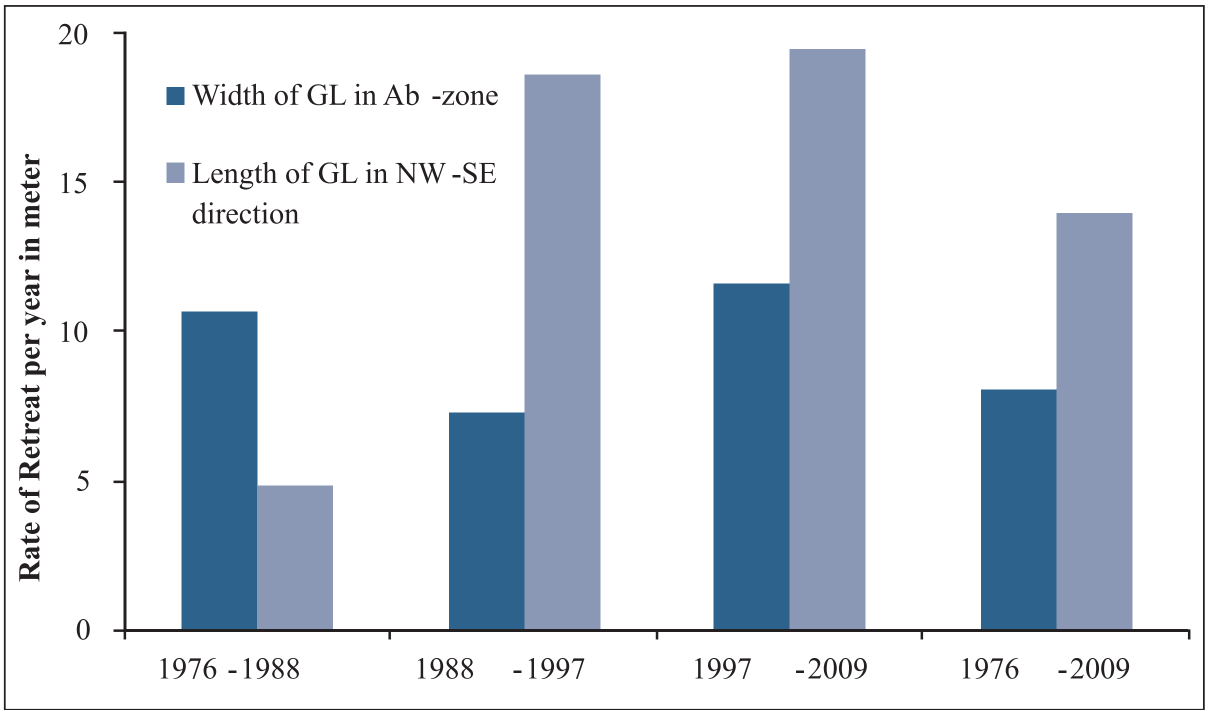


Fig.8: Graph showing the rate of retreat of East Rathong Glacier

GLACIER RETREAT IN SIKKIM HIMALAYA

The discussion paper on Himalayan Glacier (Raina V.K. 2009) stated that smaller glaciers in the Himalayas having less than 5kms length exhibit an ice thickness of the order of 250m in the cirque region and ice thickness of the order of 40-60m along the middle regions though some larger glaciers like Zemu exhibit an ice thickness of over 200m in the middle region. From 1909 to 2005, Zemu glacier has retreated approximately 863meters. However the retreat was punctuated between 1988 and 2000 with an advancing of 92m (7.67 per year). The areal coverage of glacier increased during this period. In a nutshell, Zemu retreated between 1976-1988, advancing for 12 years (between 1988-2000) and again retreated thereafter. Therefore, one cannot correlate the impact of global warming on the glacier on the basis of these small term variations in Sikkim (MoEF Discussion Paper on Himalayan Glacier).

Table 2: Glacier terminus position changes in Sikkim (1976-2005)

Name of Glacier	Area in 2005 (Km^2)	1976-1988	Rate (1976-1988)	1988-2000	Rate (1988-2000)	2000-2005	Rate (2000-2005)	Total	Average
Kangkyong	23.31	-78	-6.50	-28	-2.33	-124	-20.67	-230	-7.67
Talung	25.51	0	0	-31	-2.58	-102	-17.00	-133	-4.43
Zemu	90.94	-495	-41.25	92	7.67	-19	-3.17	-422	-14.00

(*Source:* MoEF Discussion Paper on Himalayan Glacier-2009)

La Touche, 1909

V.K. Raina,1965

Puri, 1999

Milap Chand Sharma, 2008

Fig.9: Photograph showing the Snout position of Zemu Glacier, Sikkim.

Study of 57 glaciers in the Teesta basin between 1997 and 2004 from satellite imagery, shows that glaciers have a mean size of 7.15 sqkm and the change in area is 0.36 sqkm only (Kulkarni 2010). There are many evidences of moraine dammed lakes formation and their areal increase due to retreat of glacier. Recent studies (Kulkarni 2010) by monitoring the Lhonak Lake of Teesta river basin using multi-year satellite data revealed that there is an increase of Lhonak Lake from 23 Hectares to 110 Hectares from 1976 to 2007. This increase in lake area was caused by retreat and melting of glacier terminus (Kulkarni 2010).

CONCLUSION

East Rathong is one of the Healthy glaciers in the Teesta basin (Rangit Sub-basin). Satellite images, SOI topo-sheets and field investigations were used to map and delineate the present and past glacial extent of glacier under study. Maximum extent of past glaciations was estimated by using IRS LISS-III image, topo-sheets and field data. Terminal moraine was located at 1.12 km downstream of present position of terminus (Field Observation). The position of Terminal moraine in 1965 was estimated from the Survey of India topographic maps and field investigation. Snout position was determined through satellite imagery as well as field investigation. The study shows a total recession of the glacier by about 460 meters during the period of 33 years (1976 - 2009), and 234m during last 12 years with an average rate of 19.5 m/year and during the last twelve years an area of about 2.12 hectares was completely deglaciated (front of the present glacier snout), the ice field was also reduced from 405m to 343m from the year 1997 to 2009.

The digital elevation model of the glacier clearly shows the glacier as a healthy valley glacier. Investigations of the glacier strongly indicate glacier retreat as a result of global warming. As glaciers are retreating, it is expected that tributary glaciers will detach from main glacial body and become independent glaciers or cirques. During the last three decades, nearly 9 percent of the glacier length was reduced from the main body of the glacier.

The recently developed moraine dammed lakes in the deglaciated area indicate the rate of retreat and it has increased in the last decade. Sikkim glaciers are located at low latitude and high elevation as compare to Western Himalayan glaciers. The elevation of the glaciers ranges between 4500 meters to 8000 meters, therefore the individual glacier has the individual characters like slope, aspect, size, length, width, depth etc. So while the small glacier like East Rathong has shown retreat, but glacier having large dimensions like Zemu Glacier has not shown any response to global warming.

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East Rathong glacier is south facing and under stress from climate change impacts

AUTHORS

Keshar Kr. Luitel
Department of Mines, Minerals & Geology,
Below Tashiling Secretariat, Gangtok-737101, Sikkim.
Email: keshar.luitel@gmail.com
(Corresponding author)

D. G. Shrestha
Department of Science & Technology, Govt. of Sikkim,
Development Area, Gangtok-737101, Sikkim
Email: dhiren_dgs@yahoo.com

N.P. Sharma
Sikkim State Council of Science & Technology, Govt. of Sikkim,
Development Area, Gangtok-737101, Sikkim
Email: naresh_hvs@yahoo.co.in

R. K. Sharma
Sikkim State Council of Science & Technology, Govt. of Sikkim,
Development Area, Gangtok-737101, Sikkim
Email: gautam84rk@yahoo.com